Chapter 2

IMPLEMENTATION

A. INTRODUCTION

This chapter describes the following investigations and field activities carried out within the limits of the project area: LIDAR imagery analysis, detailed mapping, geophysical survey, mechanical test trenching, and compaction testing (Figure 2.1).

B. LIDAR IMAGE ANALYSIS

LIDAR (Light Detection And Ranging) is an optical remote sensing that can measure the distance to, or other properties of, targets by illuminating the target with laser light and analyzing the backscattered light. LIDAR technology has applications in archaeology, geomorphology and contour mapping as well as a host of other fields. LIDAR operates on the same principles as radar and sonar.

LIDAR has many applications in the field of archaeology including aiding in the planning of fieldwork, mapping features beneath forest canopy, and providing an overview of broad, continuous features that may be indistinguishable on the ground such as the now-buried 17th-century cart road. LIDAR can be used to create high-resolution digital elevation models (DEMs) of archaeological sites that can reveal micro-topography that is otherwise hidden by vegetation. LIDAR-derived products can be integrated into a Geographic Information System (GIS) for analysis and interpretation. Its ability to penetrate forest canopy has led to the discovery of features that were not distinguishable through traditional geo-spatial methods and are difficult to reach through field surveys. The intensity of the returned signal can be used to detect features buried under flat vegetated surfaces such as fields, especially when mapping using the infrared spectrum. The presence of these features affects plant growth and thus the amount of infrared light reflected back.

LIDAR data was obtained from the National Oceanographic and Atmospheric Administration's "2007 Delaware Coastal Program Lidar: Kent and New Castle Counties" (Figure 2.2). The data acquisition occurred in 7 missions between March 31 and April 5, 2007 in Kent and New Castle Counties, Delaware. The data have been classified and were flown to derive bare earth contours at two foot intervals. Multiple returns were recorded for each laser pulse along with an intensity value for each return. The points have a 1.4 m ground spacing (1.0 m ground spacing within the Wilmington Urban Area). This data set is a raster file of z values with 3712 columns and 2081 rows. The data set was extracted from a larger classified data set and only includes points classified as Ground, Model Key-point (mass point), and Bathymetric LiDAR Points within the geographic bounds (Figure 2.3).

Figure 2.4 shows the last LIDAR returns or bare earth model of the possible cart road crossing of Spring Branch. Three arrows have been sketched over Figure 2.4. The first arrow shows an area where the stream channel has an unusual configuration (trending southwest-northeast). The streambed widens at this point. This could be due to springs discharging to the stream or historic modification of the channel. The second arrow points to an area where there is a gentle slope down to the stream channel from the southwest. This is near one of the shoals or riffles observed in the field. The third arrow is located at the bend in the stream channel. The stream channel morphology changes at

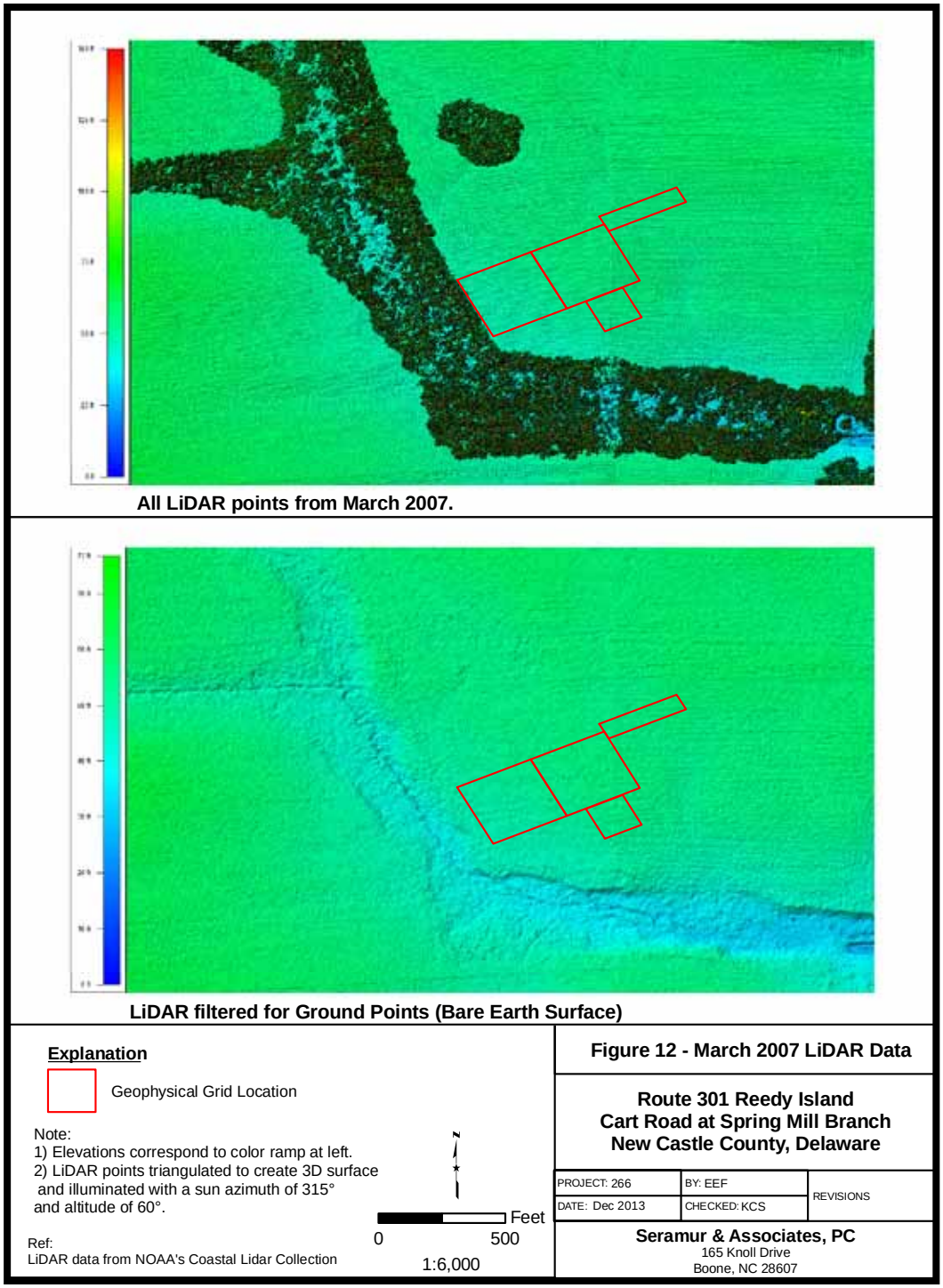


Figure 2.2. LiDAR Points (Seramur Figure 12).

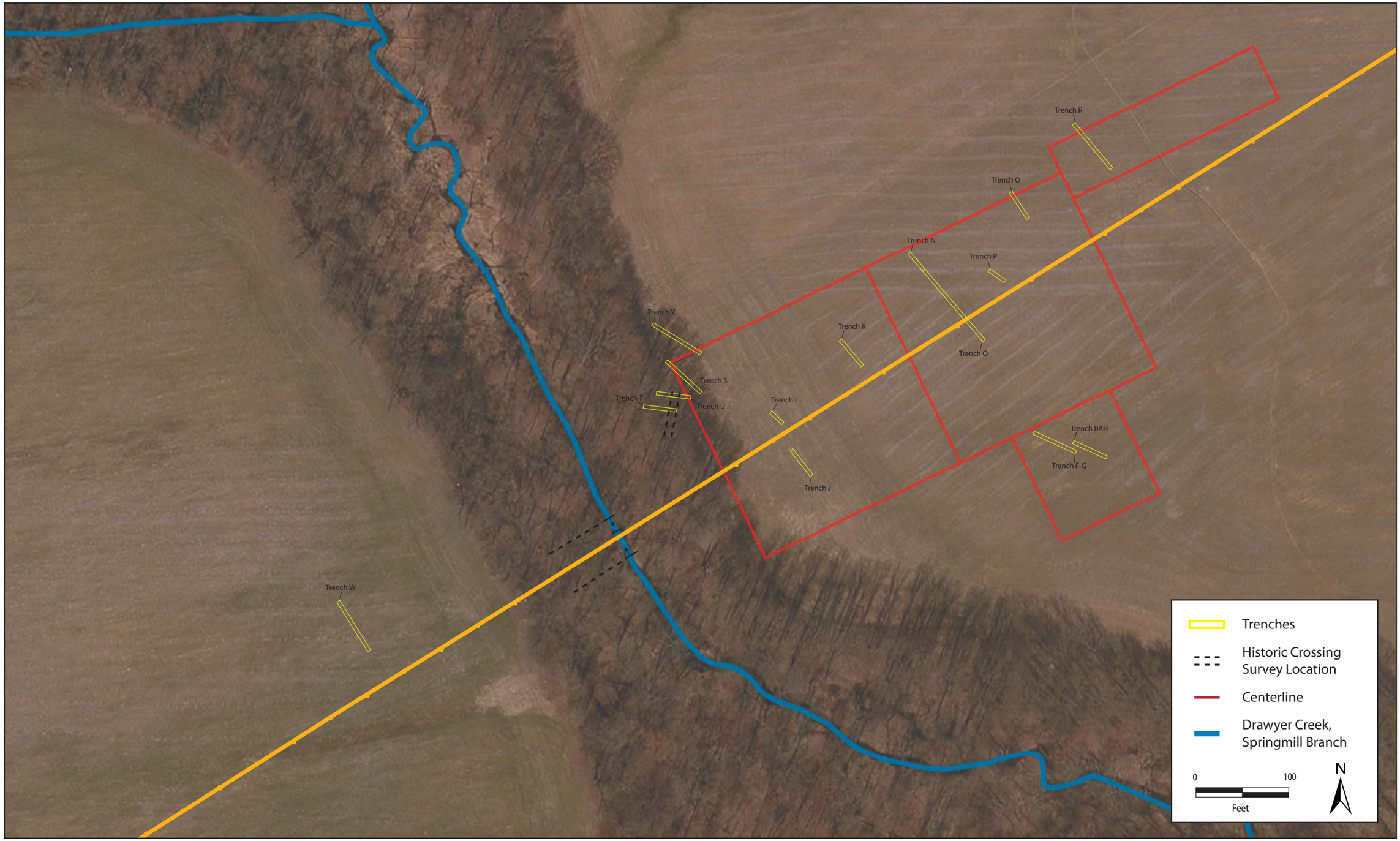


Figure 2.1. Map of Project Area showing location of Geophysical Grid, Historic Crossing Survey Location, and Excavation Trenches.

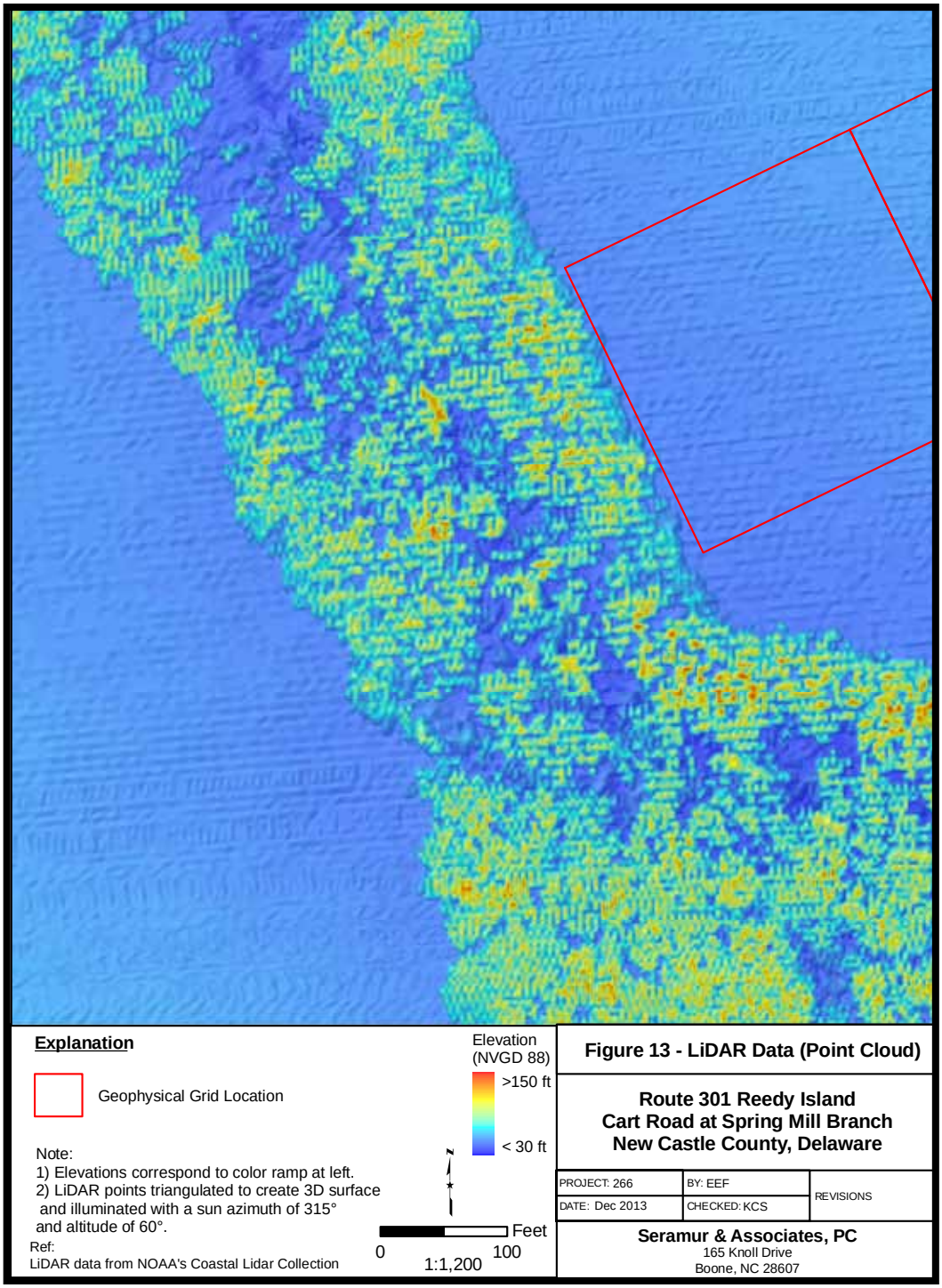


Figure 2.3. LiDAR Point Cloud at Historic Crossing (Seramur Figure 13).

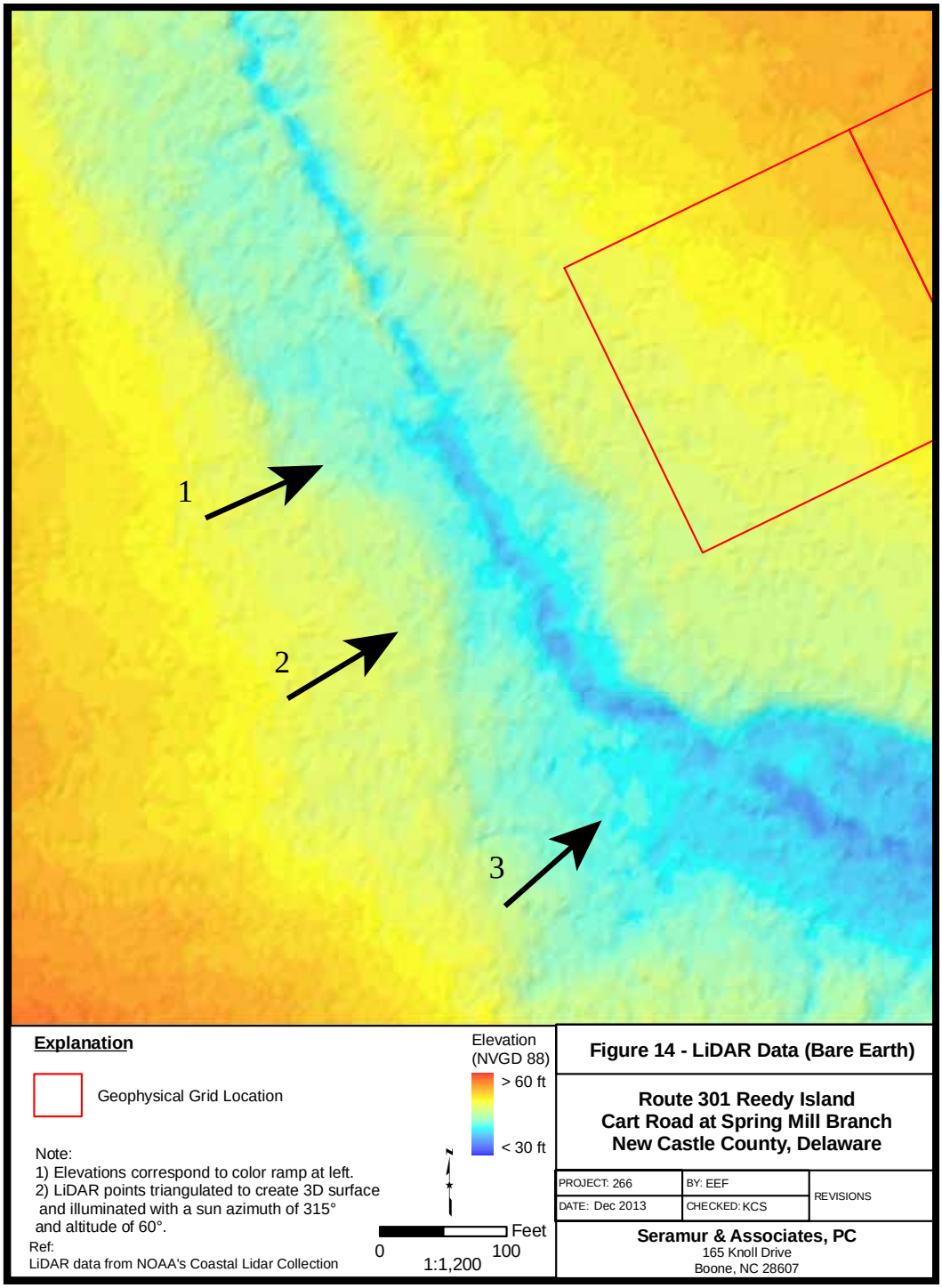


Figure 2.4. LiDAR Bare Earth image at Historic Crossing with possible crossing sites indicated on LiDAR marked by arrows (Seramur Figure 14).

this bend in the river. Upstream the channel is narrow and appears relatively confined. Downstream of the bend the channel appears to meander across a wide lowland area (broad dark blue area on Figure 2.4). A historic crossing of Spring Branch would have been more practical upstream of the bend, along the narrow confined portion of the channel.

C. TESTING FOR PHYSICAL SURVIVAL OF THE EAST SPRING BRANCH CROSSING THROUGH NON-INTRUSIVE SURVEY

Testing the predictive model involved mapping of the probable ford location on the East Spring Branch between Segments 5 and 6 in Section 1 of the U.S. Route 301 corridor (Figure 2.5). The probable ford is the only place where the stream can currently be crossed without sinking into the streambed. It also aligns with the projected line of the section of the cart road identified to the west (Hunter Research, Inc. 2011b: Chapter 3). On the east side of the stream an apparent borrow pit and a probable ramp leads to or away from the ford location. There are also two large pieces of granite, which is not native to this area of Delaware, lying adjacent to the stream at the probable ford.

Mapping required clearing of understory vegetation to facilitate use of the total station. This clearance was undertaken in accordance with prevailing environmental controls and conditions, clearing only briars, vines, small diameter trees and dead wood. The mapping involved close-interval contour mapping based on a surveyed grid tied to Delaware Department of Transportation's (DelDOT) established stations as well as showing specific features and topographic details.

On the east side of the Spring Mill Branch a baseline was established along the perimeter of the wooded upland within the agricultural field. Survey points were established every five feet along the baseline and every five feet perpendicular to the baseline down to and across the Spring Mill Branch. The resulting map provided detailed, two-foot contour resolution of the area around the wooded crossing (Figure 2.5). Elevations ranged from 42 feet above mean sea level (AMSL) to 54 feet AMSL. Prior to clearing and contour mapping of the area, a potential roadway was noted heading northeast up and away from the probable ford roughly along the alignment of the centerline. Following the removal of the understory the initial trajectory seemed less likely as the gradient would have been difficult to traverse with a heavy payload. Clearing of the understory did however reveal another more likely path heading north-northeast on a 45 degree angle away from the centerline crossing of the stream at the probable ford. Along this trajectory there is a visible disruption in the natural course of the contour lines. Trenches T and U positioned to investigate this alignment, encountered traces of a pair of probable parallel ruts (see below). Another disruption of the natural contours is visible immediately northwest of Station 639+00 suggesting perhaps another parallel alignment situated 25 feet east of the alignment observed in Trenches T and U. Due to mature vegetation in this area and budget constraints this potential alignment was not investigated using subsurface testing.

On the west side of the Spring Mill Branch clearing of the understory and close interval mapping show a disruption of the natural contours about 40 feet northwest and 40 feet southeast of the centerline suggesting the cart road may have meandered widely from side to side avoiding potential hazards. No subsurface testing was conducted on this side of the stream.

D. GEOPHYSICAL SURVEY

1. Methods

The combined Ground Penetrating Radar (GPR) and Gradiometer Survey was undertaken with the objective of identifying the signature of the cart road. Approximately one acre of surface area was initially scheduled to be covered in the field on the east side of the East Spring Branch. This was increased to 3.7 acres in the field.

The study area, located in an agricultural field, was tilled and disked prior to the investigations and planted with a winter cover crop that enabled smooth running of the geophysical equipment across the ground surface. Hunter Research marked an area approximately 250 foot square on the east side of Spring Mill Branch that aligned with the cart road on the west side of the stream. Seramur & Associates laid out survey grids to collect data along 0.5 meter transects. Grids 1 and 2 were each 76 square meters (249.4 feet by 249.4 feet). Each grid approximates the size of the initial target area laid out by Hunter Research. Grid 2 was added to Grid 1 along the alignment of the cart road (Figure 2.6). Grids 1 and 2 were divided into 4 sections (A through D) for the GPR survey. This limits the size of the data files and allows the data to be processed at different target depths across the terrain.

The GPR data was processed at the end of each day and evaluated. Linear anomalies were observed crossing the northern half of Grids 1 and 2. Grid 3 was therefore added onto the northeastern corner of Grid 2 to follow these anomalies (Figure 2.6). Grid 4 was added to an elevated area south of Grid 2 to assess if there was a southern route for the cart road in this area. Hunter Research had reported a possible historic site in the area of Grid 4. The GPR system was available for a few hours at the end of the budgeted field time. Grid 4b was added to widen GPR coverage of this southern survey area.

The GPR survey was completed using the Geophysical Survey Systems, Inc. 400 MHz antenna and a SIR-3000 Single Channel GPR Data Acquisition System. Radanã software was used to produce a 3-dimensional (3-D) model of the geophysical data. Magnetic field data was collected using the Geometrics Cesium Vapor G858 Magnetometer. Gradiometer data was obtained by using two vertically separated magnetometer sensors that measure changes in the earth's magnetic field along the grid transect. The gradient between the magnetometer readings from each sensor was recorded and used to map anomalies across the survey area. MagMapperã software is used to export the magnetic field gradient data into X, Y, Z ASCII columnar format files. These data files were imported into Surferã software where they were compiled into gradiometer images. The data was processed to eliminate extreme gradiometer measurements (those exceeding $\pm$15 nanoTesla).

The GPR and gradiometer grids were compiled in Adobe Illustratorã and exported as tiff files. Tiff files were then imported into ArcGIS Desktopã Geographical Information Software to georeference the compiled grids. Geophysical data was collected along survey lines spaced 0.5 m apart. The grid layout and orientation are shown in Figure 2.6, with the X and Y values for the grid corners labeled.

2. Results

The GPR data is presented in Figures 2.7 and 2.8. The fields had been plowed in a northwest-southeast orientation in the past. The 3-D models of GPR data were sliced to depths between 0.45 to 0.65 m. The plow scars produce strong linear anomalies in the northwest-southeast direction. Some of these scars extended to a depth of 0.5 m. The slice thickness was varied from 0.1 to 1.0 m during the data processing to determine the best thickness for identifying GPR reflectors (anomalies) potentially associated with

Figure 2.5. Topographic Survey of the postulated Cart-Road Crossing of the East Spring Branch.

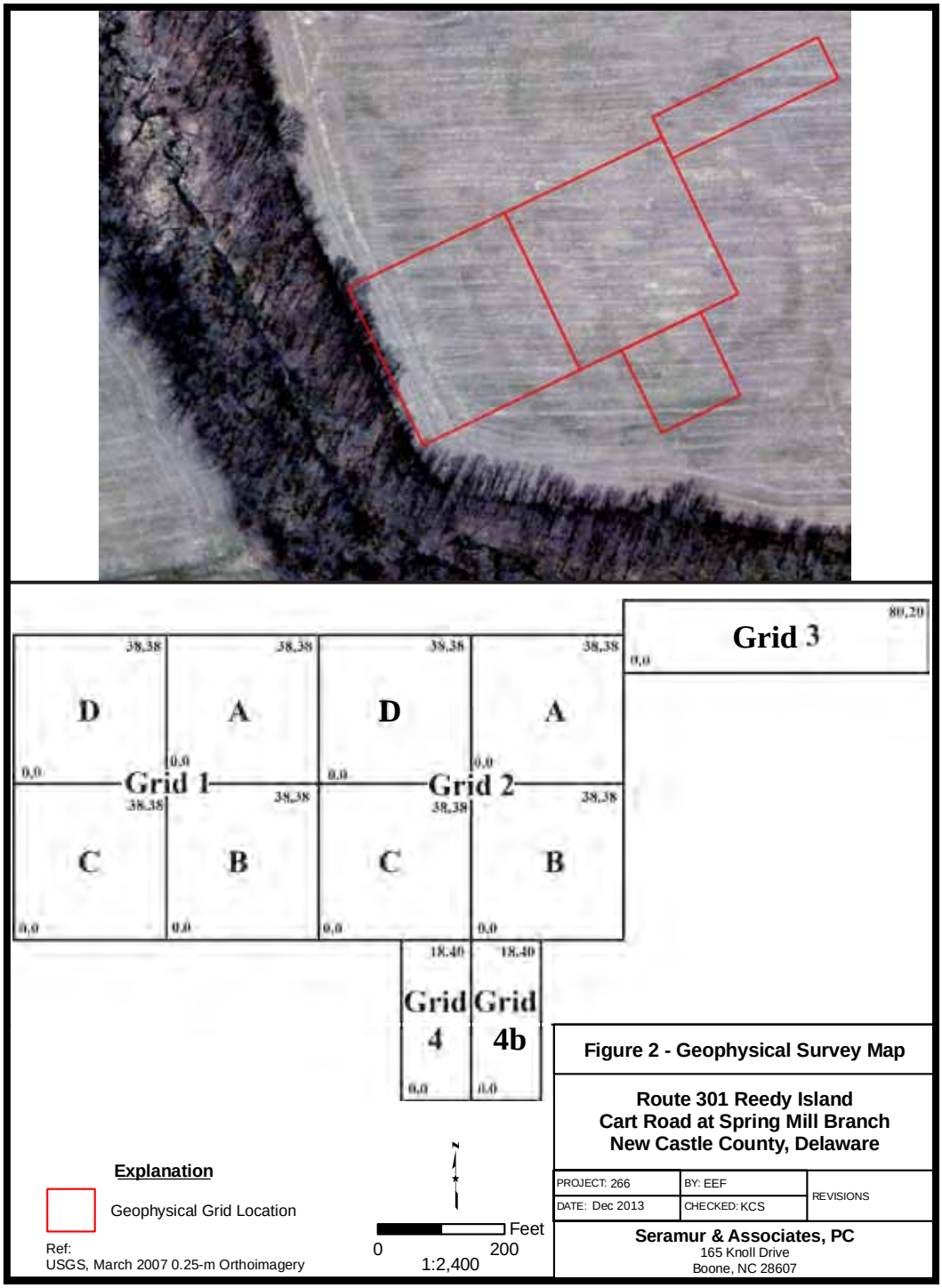


Figure 2.6. Geophysical Survey Grid (Seramur & Associates, PC 2013, Figure 2).

the cart road. Linear anomalies that could possibly represent the cart road appear to be best illustrated using a slice thickness of 0.2 m or 20 cm. GPR reflections imaged in the radar data were selected at depths between 35-55 cm, 45-65 cm and 55-75 cm. Each sub-grid was evaluated separately and the appropriate depth for the grid slice was selected.

The cart road orientation was projected to range between southwest-northeast to east-west. This is an orientation perpendicular to, or oblique to, the direction (north-south) that the GPR data was collected. Collecting data oblique or perpendicular to the direction of the target anomalies reduces the possibility of introducing artifacts into the GPR data. A background of dispersed GPR reflections occurs across the west side of Grid 1 (Figure 2.7). This area is on the slope up from the Spring Mill Branch drainage. Sediment eroded off the upland surface has accumulated on this slope. Deep plow scars produce relatively strong northwest-southeast orientated reflections across the central survey area (Figure 2.7). The central and eastern grids are located on the upland surface. These plow scars extend down into the B horizon or subsoil.

Two prominent east-west linear GPR reflections extend across the northern portion of Grids 1 and 2 (Figure 2.9a). Proposed trench locations I, K, N and Q were located across these anomalies (Figure 2.9b). The spacing of these parallel anomalies is about 6 to 8 feet. Two additional sets of parallel linear anomalies were identified in Grid 2 (Figure 2.9c). Trenches O and P were located across these southwest-northeast trending anomalies (Figure 2.9d). There is an elongate, rectangular area with a low reflection density in Grid 1 (Figure 10a). Two southwest-northeast trending linear anomalies were traced through this area and Trench J was located across these anomalies (Figure 10b). Several east-west to southwest-northeast trending linear anomalies are located in southern Grid 2 and Grids 4 and 4b (Figure 2.7). A rectangular outline of GPR reflections was noted in Grid 4b (Figure 2.8). Hunter Research excavated trenches B-A-H and G-F across these anomalies (Figure 2.8). Trench B-A-H was excavated along the southwest side of the rectangular anomaly. Hunter Research reported a large pit feature in the trench near point B.

The gradiometer data is presented in Figures 2.11 and 2.12. Three anomaly types were observed in the gradiometer data. The first were large oval features, which are addressed in the Delmarva Bay discussion below. The second were a series of linear southwest-northeast trending anomalies showing an elevated magnetic gradient (Figures 2.11 and 2.12). These linear anomalies did not show up in the GPR data. They could be related to bedding or changes in iron content in the underlying fluvial and marine sediment. The G858 magnetometer is very sensitive and metallic objects produce a strong magnetic signal in the gradiometer data. These show up on the gradiometer images as polar (white and black) anomalies (Figure 2.11). These metallic anomalies are circled on Figure 2.12. There is a line of these metallic anomalies that trends along the linear set of GPR anomalies in the northern portion of Grids 1 and 2 (Figures 2.8 and 2.12).

Several areas of interest were noted in Grids 4 and 4b on the gradiometer and GPR data. These were flagged in the field using plastic stemmed pin flags and assigned letter point locations A through H for later identification and testing by the archaeological field team. These areas of interest are referred to in the text here after as “Points”. They include a complex of circular anomalies in the vicinity of Points G, H and F (Figure 2.11). At the conclusion of the geophysical fieldwork and analyses, a report was prepared summarizing the survey procedures and results (Appendix A). Anomalies mapped across the survey blocks were identified on site maps. It was anticipated that the GPR and gradiometer surveys would determine the location of soil disturbance related to historic cart road

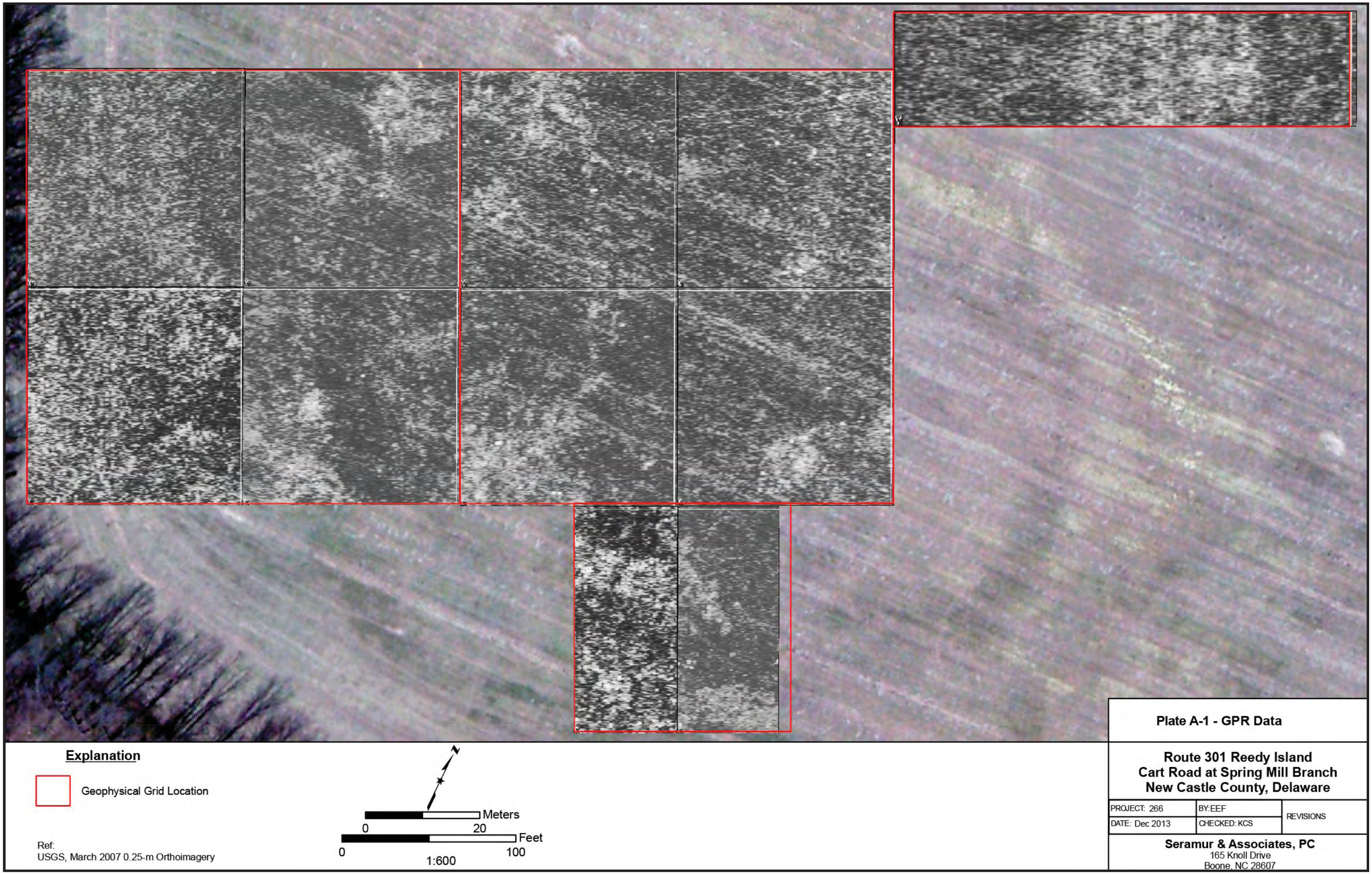


Figure 2.7. Ground Penetrating Radar Data (Seramur & Associates, PC 2013, Figure A1).

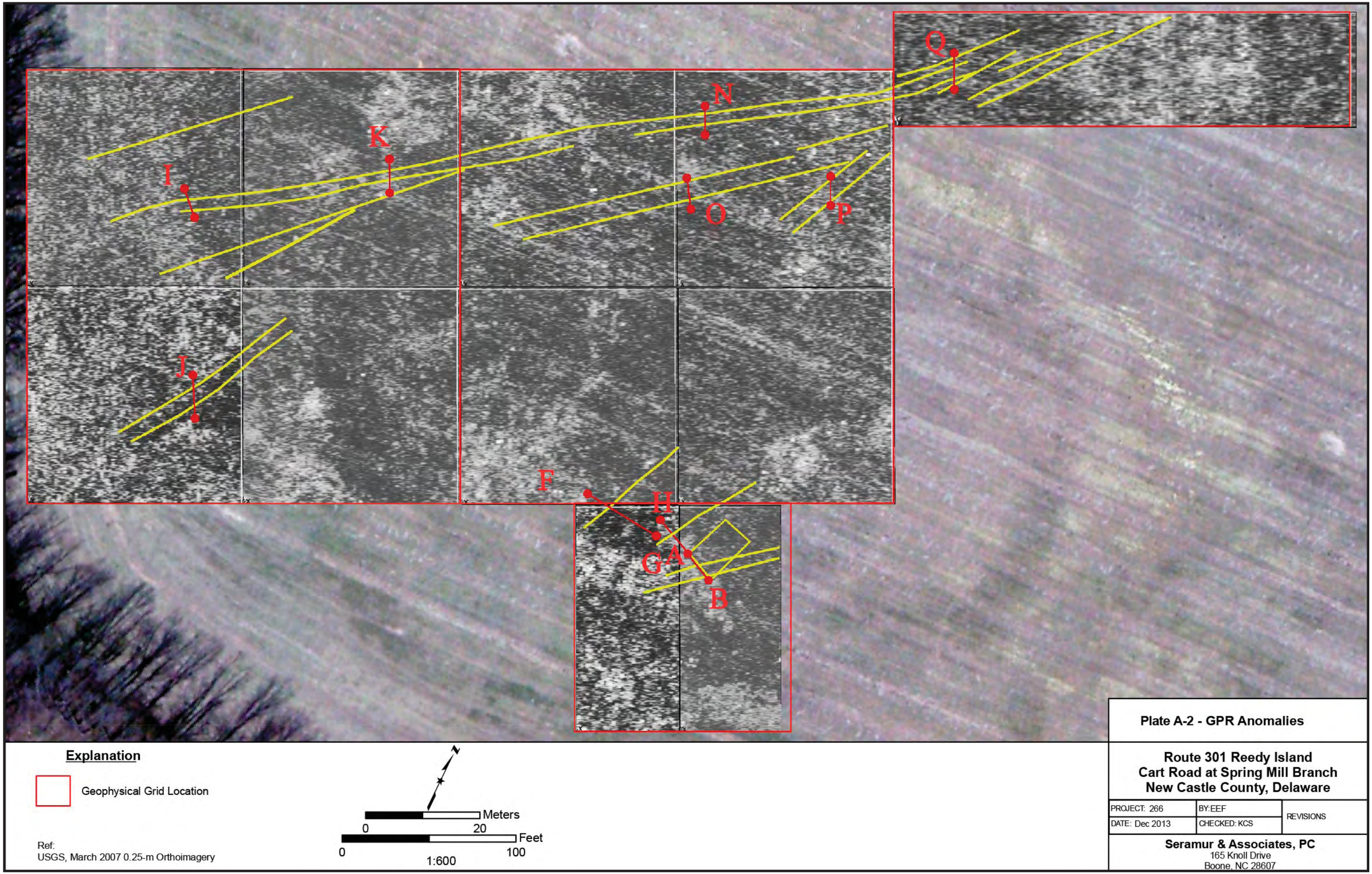


Figure 2.8. Ground Penetrating Radar Anomalies (Seramur & Associates, PC 2013, Figure A2).

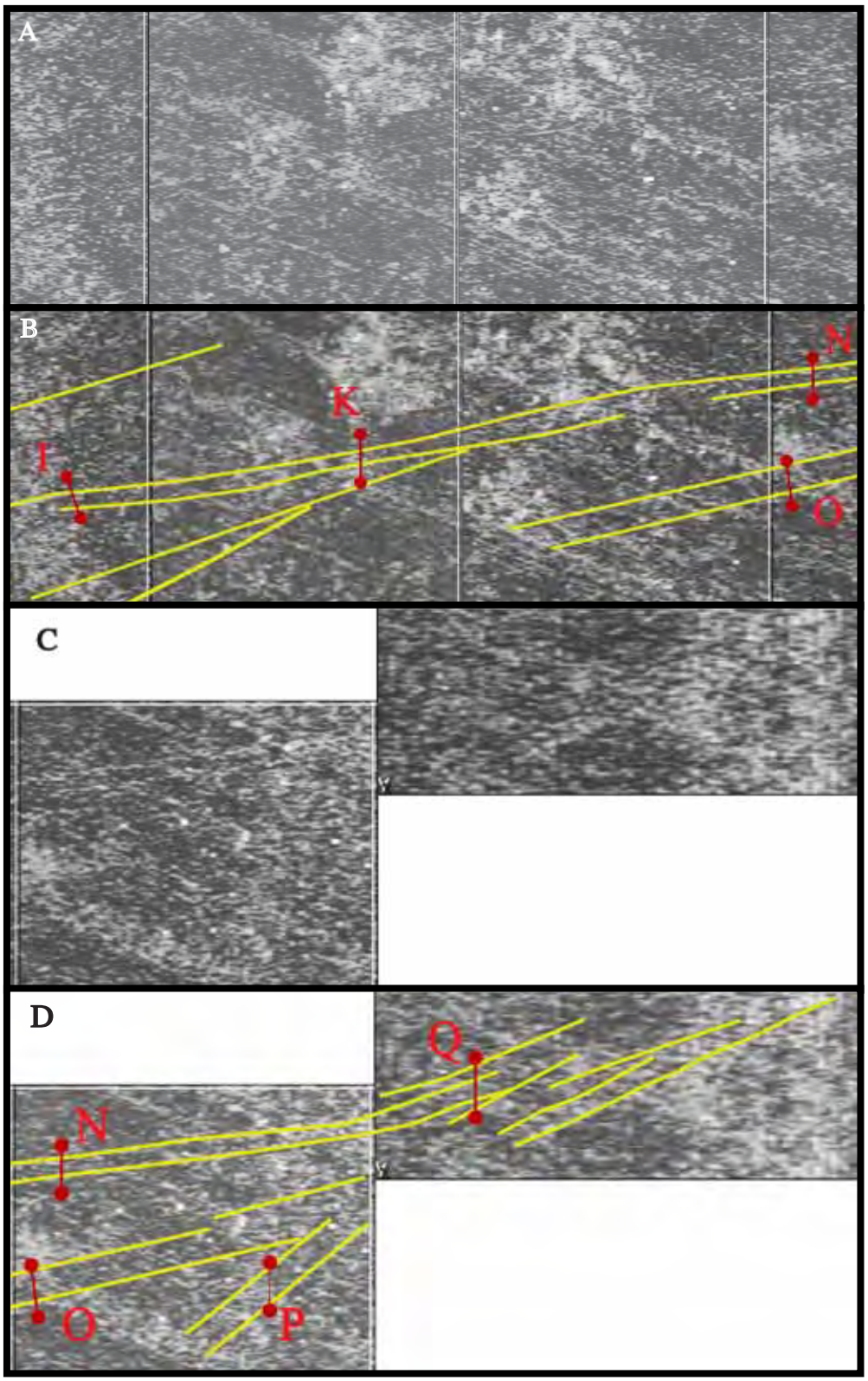


Figure 2.9. East-West Linear GPR Reflections. Recommended excavation locations shown in red (Seramur & Associates, PC 2013, Figure 3).

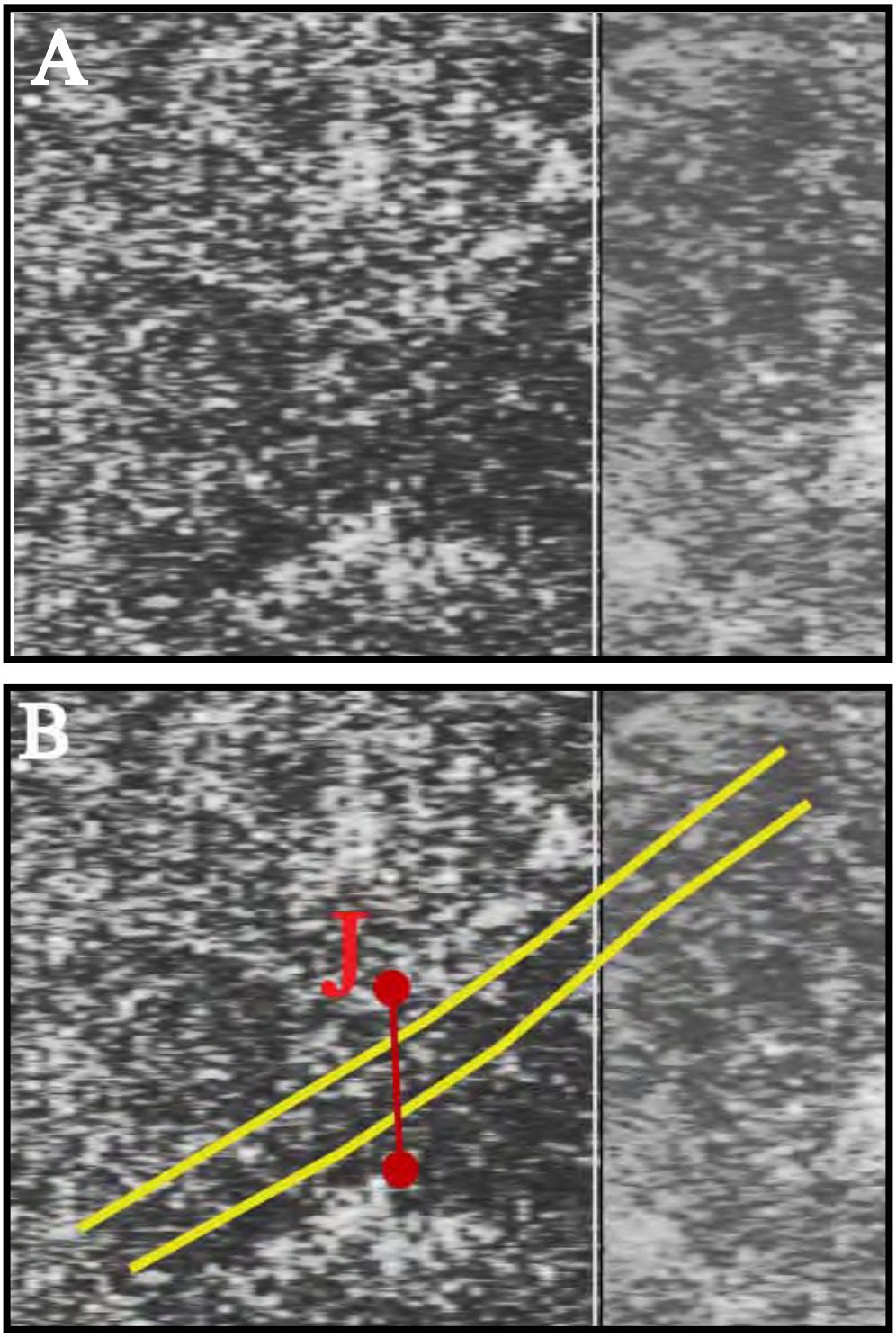


Figure 2.10. Elongate Rectangle in Grid 1 with low-density GPR Reflections (Seramur & Associates, PC 2013, Figure 4).

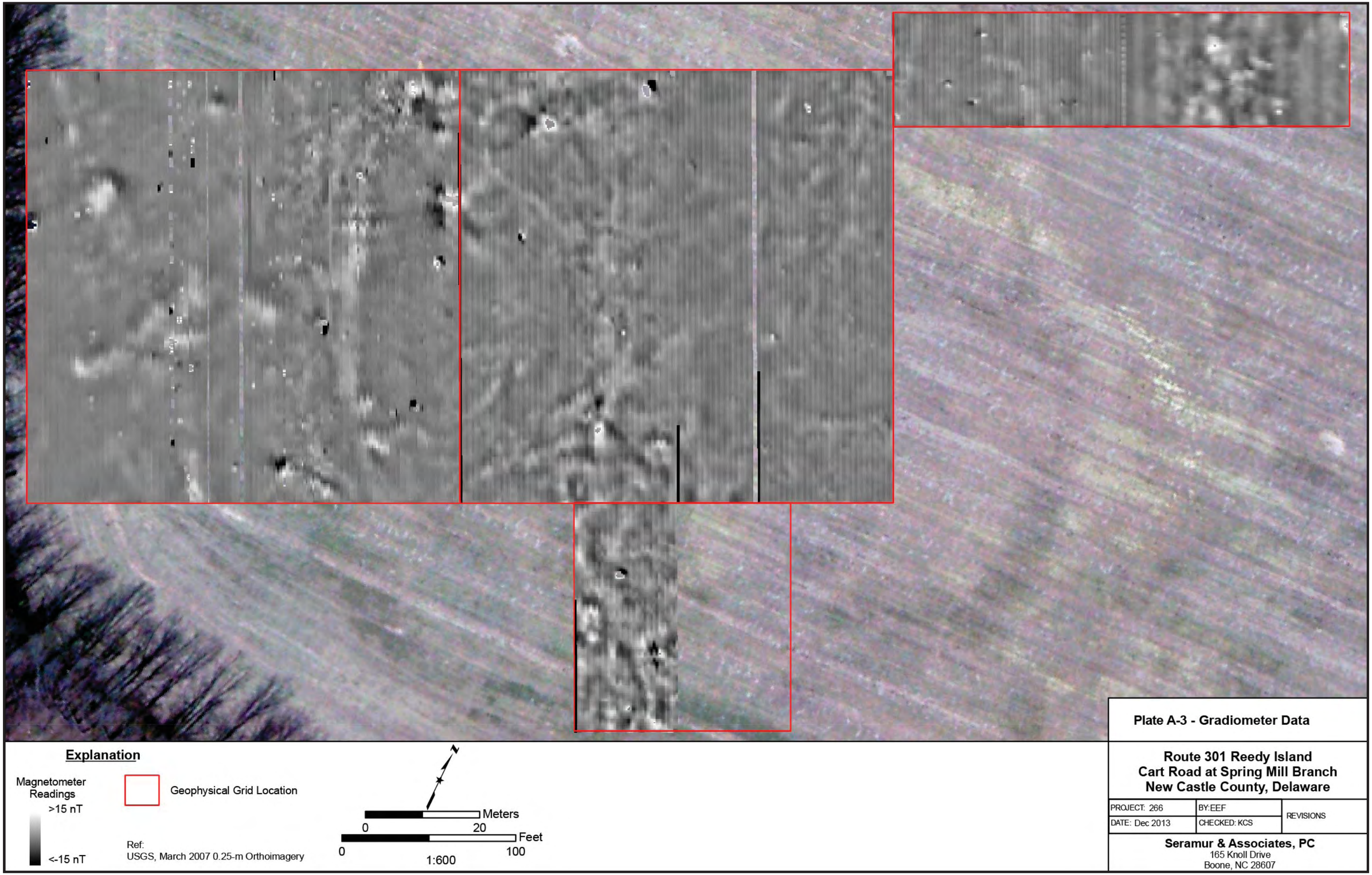


Figure 2.11. Gradiometer Data (Seramur & Associates, PC 2013, Figure A3).

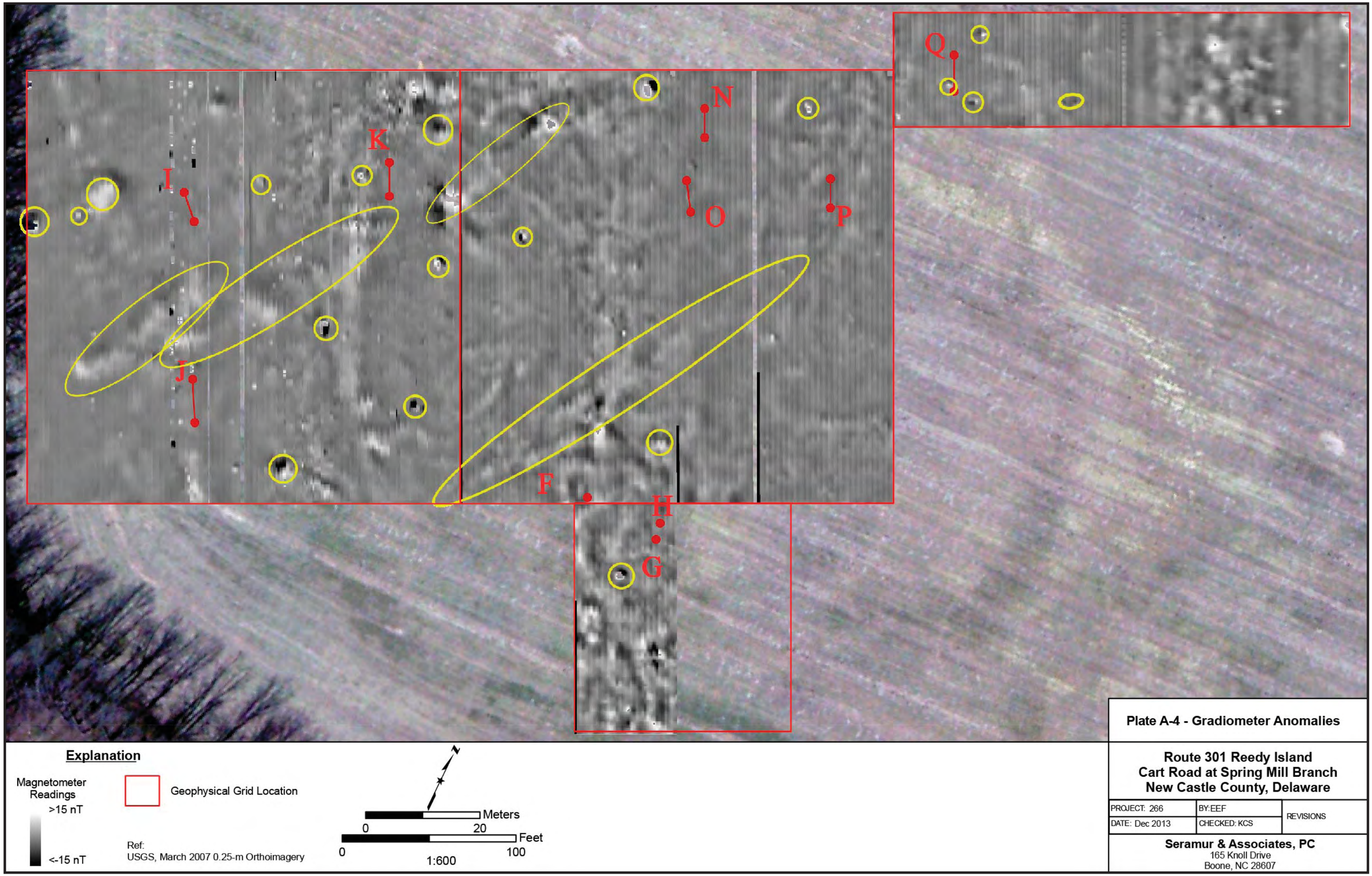


Figure 2.12. Gradiometer Anomalies (Seramur & Associates, PC 2013, Figure A4).

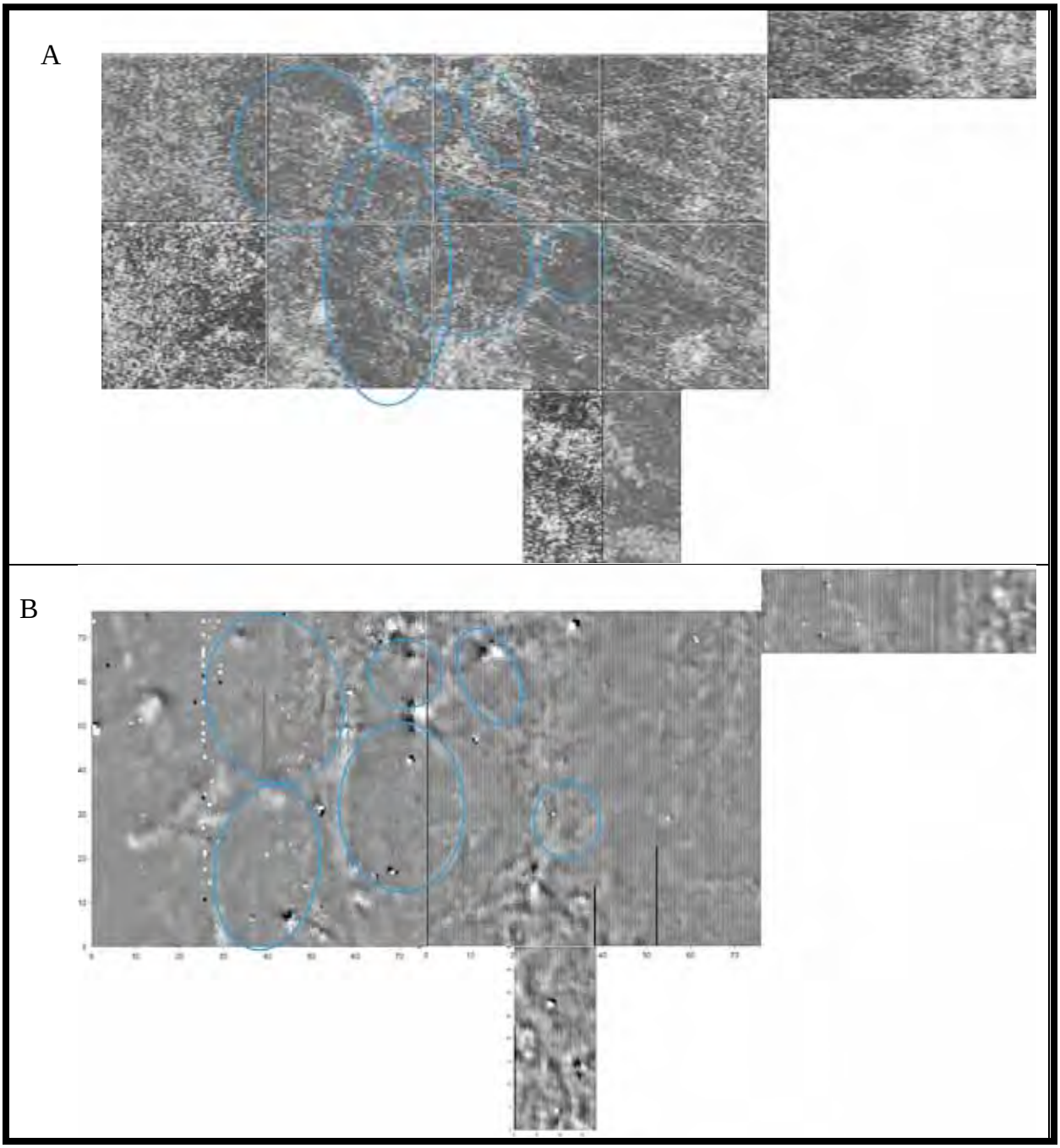


Figure 2.13. Oval subsurface features showing in Ground-Penetrating Radar (A) and Gradiometer (B) data. These are interpreted as former seasonal wetlands or Delmarva Bays. Note possible fenceline marked by white dots (magnetic anomalies) roughly along Easting 30 on Gradiometer mapping. (Seramur & Associates, PC 2013, Figure 5).

and related features across the property. On receipt of the report, Hunter Research adjusted the original plan for testing based on the GPR data.

3. Delmarva Bays

The coastal plain sediments in the project area are mapped as the Columbia Formation, sand with gravel and beds of clayey silt. Shallow deposits in the study area are silt to very fine sand. Soil is mapped as the Othello Silt Loam and the Reybold Silt Loam. The Othello Silt Loam is mapped along the western side of the field and forms in depressions, flats and swales. The Reybold Silt Loam is mapped on the upland surface and forms on interfluves. Both of these soils form in silty aeolian sediment deposited over fluviomarine sediment (USDA 2013). Un-drained depressions formed in the Columbia Formation are commonly referred to as Delmarva Bays (Davias 2012; Ramsey 2005). These are also known as wet flatwood swamps and form seasonal wetlands across the Delmarva Peninsula. These wetlands occur in subtle depressions and are seasonally flooded in the spring from snowmelt and spring rains. These features are thought to be remnant Pleistocene landforms related to periglacial and aeolian processes (Newell and Clark 2008).

A circular, wooded area in the northwest corner of the farm field is not plowed because it is a seasonal wetland or Delmarva Bay. The aerial photograph of the upland portion of the study area shows several round to elliptical features (Figure 2.6). These features are visible because of slight changes in soil moisture. These features were also observed on the GPR and magnetometer data (Figure 2.13a and 2.13b). The GPR depicts these as areas of low-density reflections (Figure 2.13a). The GPR signal is attenuated by clay soils and the low-density reflections in the center of these circular features could indicate a higher clay content in the soil. The perimeters of these circular features are observed on the gradiometer data as areas with a high magnetic field gradient (Figure 2.13b). The perimeter of seasonal wetlands would experience frequent changes in moisture content. Iron precipitation occurs in areas along the top of the water table as a result of changes between reducing saturated conditions and oxidized aerated or drained soils. The rims of these circular features appear to be outlined by soil with a higher iron oxide concentration. The circular features observed in the study area are former seasonal wetlands. These remnant Pleistocene features could have been drained and plowed after European settlement.

E. MACHINE-ASSISTED EXCAVATION OF TRANSECTS ACROSS PREDICTED ALIGNMENT

An archaeologically directed backhoe with a flat-blade bucket was used to remove the plowzone from 14 trenches (B-A-H, F-G, I, J, K, N, O, P, Q, R, S, T, U, and V), on the east side of the Spring Mill Branch. These trenches measured from 17 to 100 feet in length and were 3.5 feet wide (Photographs 2.1-2.15). The trenches were positioned to cross the projected alignment of the cart road and in areas where the geophysical survey suggested that features from the cart road may have been detected as well as a possible projection of the cart road revealed following the removal of understory of the wooded area adjacent to the Spring Mill Branch during the mapping phase. The prime objective was to expose the remains of the parallel ditches/ruts if present, the methodology being deliberately similar to that employed on the west side of the creek.

An additional trench (Trench W) was excavated on the west side of the Spring Mill Branch to re-locate the well-defined ditches/ruts identified during Phase II investigations of the Reedy Island Cart Road Site 4

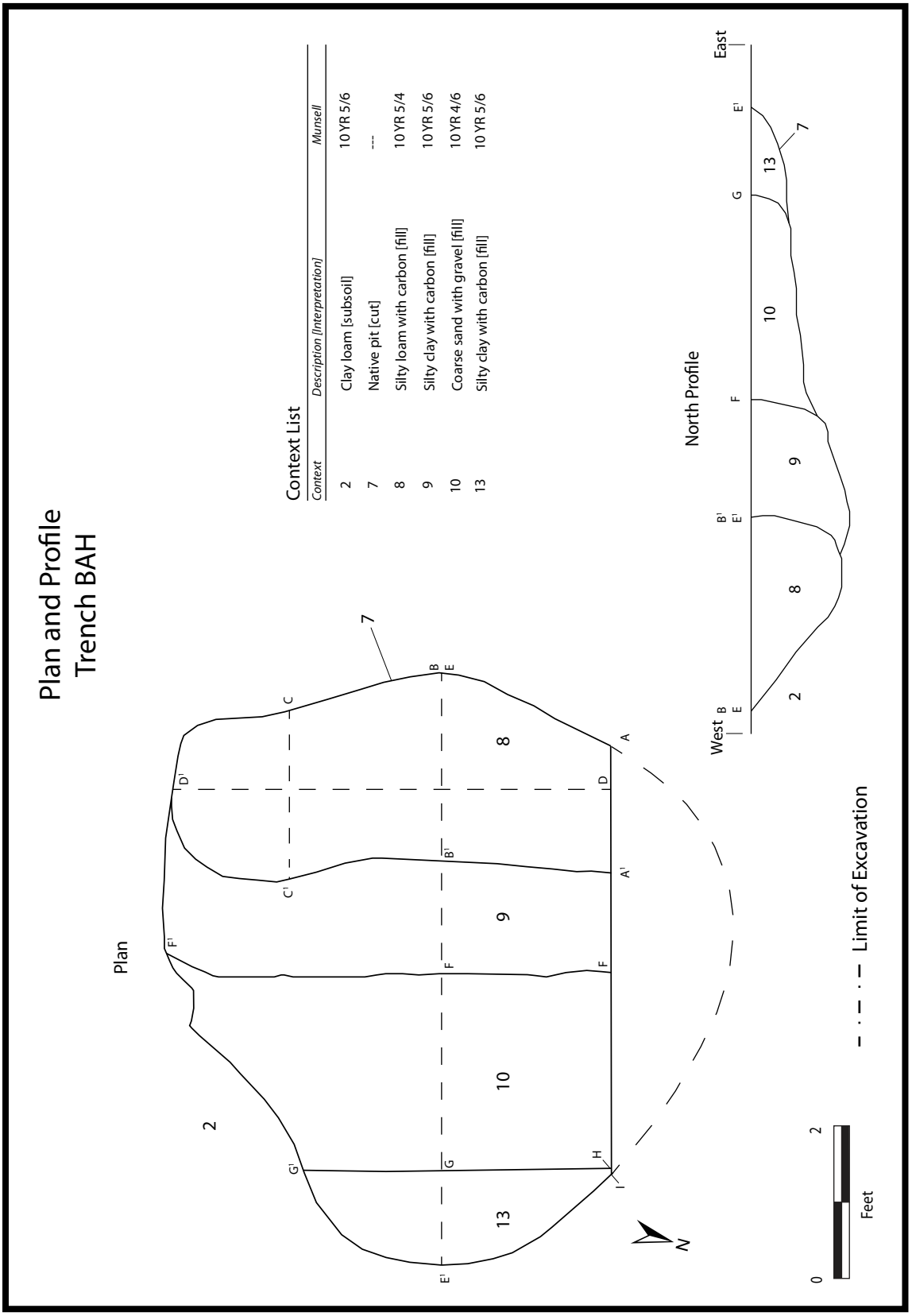
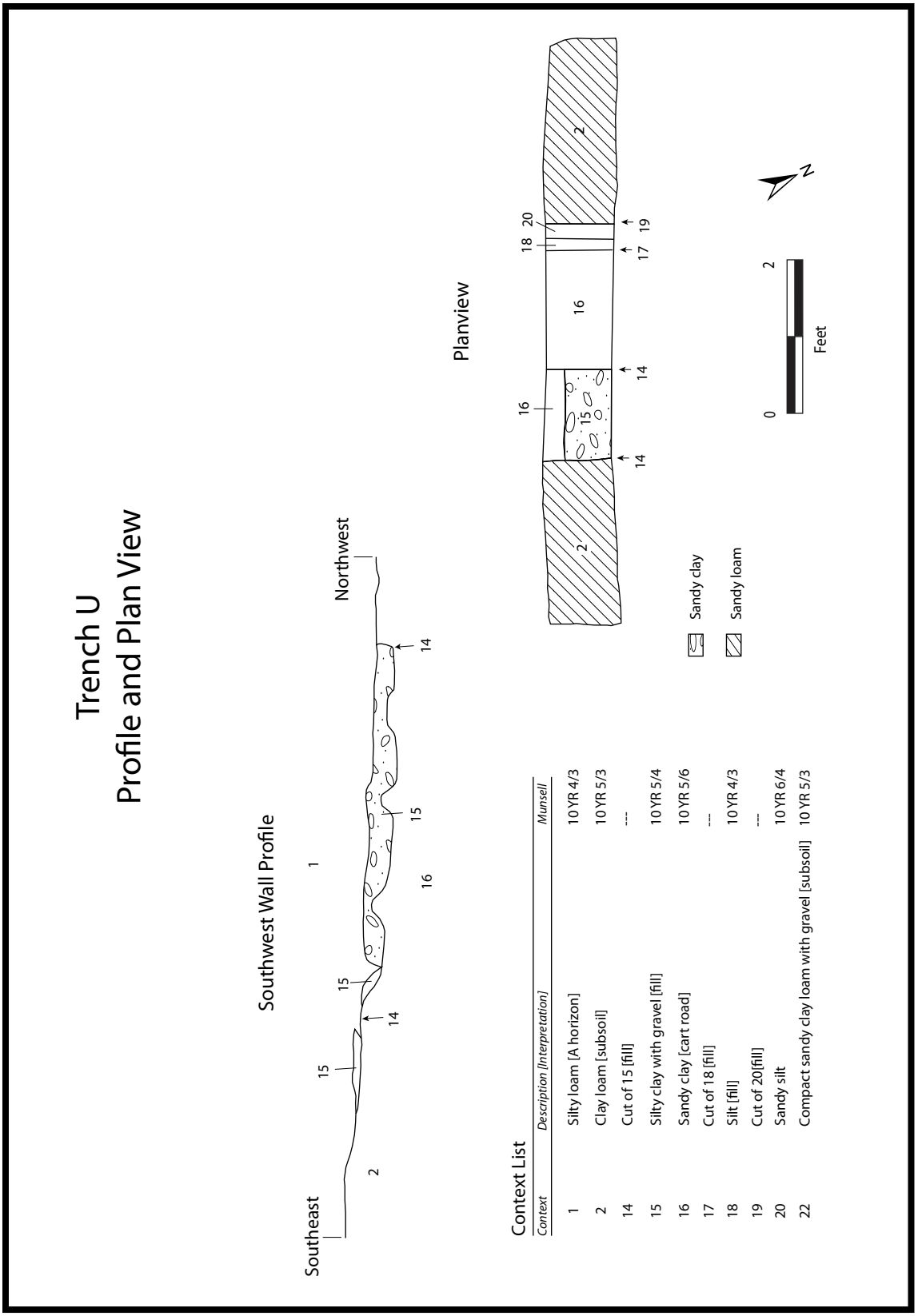


Figure 2.14. Plan and Profile of East end of Trench BAH.



Context List

Context	Description [Interpretation]	Munsell
1	Silty loam [A horizon]	10 YR 4/3
2	Clay loam [subsoil]	10 YR 5/3
14	Cut of 15 [fill]	---
15	Silty clay with gravel [fill]	10 YR 5/4
16	Sandy clay [cart road]	10 YR 5/6
17	Cut of 18 [fill]	---
18	Silt [fill]	10 YR 4/3
19	Cut of 20[fill]	---
20	Sandy silt	10 YR 6/4
22	Compact sandy clay loam with gravel [subsoil]	10 YR 5/3

Figure 2.15. Plan and Profile of Trench U.

Photograph 2.1. Reedy Island Cart Road Supplemental Testing. Trench B-A-H view showing anomaly at the east end of the trench following the removal of the plowzone, looking southeast (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-098].

Photograph 2.2. Reedy Island Cart Road Supplemental Testing. Trench F-G view looking north (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-062].

Photograph 2.3. Reedy Island Cart Road Supplemental Testing. Trench I view looking north, northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-029].

Photograph 2.4. Reedy Island Cart Road Supplemental Testing. Trench J view looking south, southeast (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-031].

Photograph 2.5. Reedy Island Cart Road Supplemental Testing. Trench K view looking north, northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-032].

Photograph 2.6. Reedy Island Cart Road Supplemental Testing. Trench N view looking north (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-034].

Photograph 2.7. Reedy Island Cart Road Supplemental Testing. Trench O view looking north (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-037].

Photograph 2.8. Reedy Island Cart Road Supplemental Testing. Trench P view looking north, northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-040].

Photograph 2.9. Reedy Island Cart Road Supplemental Testing. Trench Q view looking north (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-052].

Photograph 2.10. Reedy Island Cart Road Supplemental Testing. Trench R view looking south (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-058].

Photograph 2.11. Reedy Island Cart Road Supplemental Testing. Trench S view looking northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-165].

Photograph 2.12. Reedy Island Cart Road Supplemental Testing. Trenches T and U view looking northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-160].

Photograph 2.13. Reedy Island Cart Road Supplemental Testing. Trench U view showing light traces of the cart road ruts indicated by the pink ribbon, looking northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-159].

Photograph 2.14. Reedy Island Cart Road Supplemental Testing. Trench U close up view showing gravel filled east rut looking south (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-147].

Photograph 2.15. Reedy Island Cart Road Supplemental Testing. Trench V view looking north, northwest (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-096].

Photograph 2.16. Reedy Island Cart Road Supplemental Testing. Trench W overall view showing excavated ruts of the Reedy Island cart road, looking south (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-136].

Photograph 2.17. Reedy Island Cart Road Supplemental Testing. Trench B-A-H view showing fully excavated prehistoric pit near the east end of the trench, looking north, northeast (Photographer: Sue Ferenbach, November 2013) [HRI Neg.#13039 D1-176].

(Hunter Research 2014), and to perform comparative penetrometer testing. This trench was 63 feet long by 3.5 feet wide (Photograph 2.16).

Following mechanical stripping, the trenches were shovel-scraped and trowelled to identify and define the cultural features. Obvious plow scars were removed to avoid possible confusion with older cart road ditches/ruts. Due to heavy erosion of the topsoil-plowzone, the profile was truncated. Erosion coupled with over three hundred years of plowing appears to have erased any visual detection of the cart road on this side of the Spring Mill Branch. The only trenches with observed visual evidence of cultural activities were Trench B-A-H, which had a large deep prehistoric storage pit and Trenches T and U with possible shallow traces of ditches/ruts which were located within the protected wooded upland between the Spring Mill Branch and the agricultural field (Figures 2.14 and 2.15).

1. Trench B-A-H

This 39-by-4-foot trench was positioned to intersect with geophysical points of interest B, A and H. The plowzone [context 1], only 0.5 feet in depth, was mechanically removed with a backhoe. Following the removal of the plowzone a large prehistoric pit measuring 7.3 feet north-south by 7.8 feet east-west was encountered at the top of the B horizon at the east end of Trench B-A-H in the area of Point B (Figure 2.14; Photograph 2.17). This pit was distinguished from the surrounding B horizon [2] by its darker organic soils and upcast C horizon gravels at the top of the B horizon [context 2]. Four separate soils (silty loam [8], silty clay with carbon flecking [9], coarse sand with gravel [10] and silty clay with carbon flecking [13]) within the cut [7] of the pit were observed to be unnaturally stacked and extending to a depth of 1.3 feet below the top of the B horizon [2]. A total of 82 prehistoric lithic artifacts, three pieces of burnt clay and numerous small pieces of charcoal were recovered from the fill of the pit [8, 9, 10 and 13]. The lithics consist of 66 pieces of debitage (quartz, jasper, chert, quartzite and argillite), 7 thermally fractured rock fragments, and a quartz core fragment from context 8; eight unmodified stones (atypical of the surrounding C horizon gravels) from contexts 9 and 10; and one thermally fractured rock fragment from context 13. The debitage consists entirely of secondary and tertiary flakes between 10 and 50 mm in size, with most flakes smaller than 20 mm.

2. Trench T

Located within a thin wooded strip of upland between the Spring Mill Branch and the agricultural field, Trench T was 36 feet long by 3.5 feet wide. Both maneuvering the backhoe and removing the root infested topsoil within this woodlot proved difficult. Distinguishing the between the A and B horizons [1 and 2] was impossible given the dry soil conditions and the broken sunlight through the fragmented fall canopy. As a result the A horizon and the top of the B horizon were removed as one context to a depth 0.7 feet below the surface. Upon cleaning the surface of the machine–excavated trench it became clear that there were two separate horizons visible in the profile. There were also what appeared to be shallow ditches/ruts that had been completely removed through the mechanical excavation. To further explore the possible ditches/ruts another trench (Trench U) was laid out parallel to Trench T, in hopes that the features would continue along a projected north-south path towards the agricultural field.

3. Trench U

In order not to repeat the mistakes made in Trench T, excavation of Trench U was only initiated after an early snow shower provided the moisture needed to

better discern the differences between the soil strata. Trench U was located parallel to Trench T within a thin wooded strip of upland between the Spring Mill Branch and the agricultural field, closer to the agricultural field than T. The trench was 37 feet long by 3.5 feet wide (Figure 2.15). This area was formerly part of the agricultural field before the wooded area expanded east into the fertile plowed field. As a result the plowzone [1], which is 1.3 feet deep, represents an accretion of wind-blown topsoil added to the plowzone that typically would have been between ten inches to a foot thick. Careful removal of these sediments [1] revealed faint but discernable parallel bands running north-south through the base of the trench. These bands are likely to be cart road ruts. The east band measured 2.35 feet wide with straight, sharply defined edges [14] and the west band measured 1.6 feet wide also had straight, sharp edges [17/19]. The eastern, wider rut has an undulating bottom and appeared to have been intentionally filled with a mix of silty clay with dense gravels [15]. This may have been an attempt to fill in a widening gap in the road and to provide a rough material to prevent heavily loaded wagons, carts or sleighs from sinking into the ground. At higher levels, prior to erosion, gravel may have been placed between the ruts to provide traction to the horses or oxen. The western rut exhibits a flat bottom and was filled with silt [18] and sandy silt [20] extending down 0.2 feet below the top of the B horizon [22]. The area between the two ditches/ruts consists of compacted sandy clay [16]. Soils outside the ditches/ruts consist of clayey sand [2] towards the field and sandy clay loam with small gravels [22] closer to the wetlands.

4. Trench S

The trajectory of the projected path of the cart road observed in Trenches T and U was further examined with the excavation of Trench S adjacent to the strip of wooded upland within the field. This trench was 77 feet long by 3.5 feet wide. Penetrometer readings taken within this trench indicated that the soils were compacted, likely from heavy farm machinery making turns at the end of the field. When tractors make the turn at the end of a field they typically pull accumulated soils into the return. The increased volume translates into increased weight, thus resulting in more compacted soils. The increased compaction in this area of the field likely masked any evidence of the cart road.

F. COMPACTION STUDIES

In addition to the search for cart road features, a soil compaction investigation using a basic soil compaction meter/penetrometer was undertaken. In this instance an AMS E-280 spring-operated pocket penetrometer was used to measure the compressive strength of the soils from 0 to 4.5 tons per square foot with readings indicated by a rubber friction ring. These readings provided immediate relative compaction data across the predicted line of the road and comparative data for adjacent portions of the field. Compaction results were checked against the known road alignment on the west side of the stream, where a single narrow supplementary trench (Trench W) had been placed across the known alignment of the road to re-expose the ditches/ruts (see Figure 2.1). It was predicted that traffic along the road would compact the soils. This soil compaction was measured with the penetrometer and mapped across all excavated trenches.

1. East Side of Spring Branch

Visual evidence of the cart road was not observed in any of the trenches employed to ground truth the geophysical data on the East side of Spring Mill Branch. It was hoped that the cart road crossing the study area would have compressed the soils below the roadbed. A compacted road surface would limit

infiltration of surface water, diverting it to the side of the road. Surface water infiltration into the deeper soil horizons could soften or reduce compaction of subsoil along the edge of the cart road. Changes in both soil compaction and soil moisture content can produce anomalies within the GPR data. The penetrometer data was reviewed with respect to the GPR anomalies tested to assess possible trends related to the cart road (Appendix B).

Trenches B-A-H and G-F were excavated in an area where multiple linear and circular anomalies were observed. These anomalies were flagged in case they were structures or disturbance associated with the cart road. As discussed above, a large prehistoric pit feature was recorded in the vicinity of Point B. Penetrometer readings in the vicinity of Point B range from 1.25 to 2.4 tons/square foot (Figure 2.16) (Appendix B). These readings represent compaction values for culturally disturbed soils within the fill of the pit.

Two southwest-northeast trending linear anomalies were observed crossing line B-A (Figure 2.16). These anomalies could be associated with some of the large variations in penetrometer values recorded between 10 and 20 feet. The penetrometer data collected along lines B-A-H and G-F is quite variable (Figure 2.16) (Appendix B).

There is one area of consistently high penetrometer measurements along line G-F. The gradiometer data showed multiple anomalies in this area, possibly associated with iron oxide concentrations in the B horizon. The variable penetrometer data along these two lines could be associated with differences in iron cementation within the B horizon.

Trenches I, K, N and Q were located across two prominent parallel east-west linear GPR reflections (Figure 2.9a and 2.9b). Penetrometer measurements along Trenches I and N indicated soil with the highest compaction value (4.5 tons/square foot) with a few areas of softer soil (Figure 2.17)(Appendix B). The linear anomalies along line I could be associated with the lower penetrometer measurements at 4 feet and 9 feet (Figure 2.17). The linear anomalies along line N could be associated with the lower penetrometer measurements at 7 feet and 13 feet (Figure 2.17). These lower penetrometer measurements are at a similar spacing to the linear GPR anomalies but the absence of compacted soils suggests they are not related to a transportation route.

The penetrometer measurements in trenches K and Q show compacted soil in the center of the trenches and softer soil on the margins of the trenches (Figure 2.18)(Appendix B). This is the expected pattern for penetrometer readings across a smaller farm lane or access road. The compacted soil only extends from 13 to 17 feet in Trench K, which would be too narrow to be the cart road. East of Trench Q another trench (Trench R) was excavated on more level ground along the trajectory of the linear anomaly. In Trench R, penetrometer readings varied with no clear indication of the cart road.

Penetrometer testing in Trench O extended for 100 feet (Figure 2.19). This trench was located across two prominent parallel east-west linear GPR reflections (Figure 2.9a and 2.9b) southeast of similar GPR reflections investigated by Trenches I, K, N and Q. The penetrometer data shows variability across the trench except between 34 feet and 44 feet (Figure 2.19). These consistent (4.5 tons/square foot) penetrometer measurements between 34 and 44 feet could be related to soil compaction along the cart road (Appendix B). The high penetrometer measurements in Trench O show that the plow zone soils in upland areas have been eroded down to the stiff B-horizon subsoil. Visual evidence of the cart road has been eroded from this portion of the study area.

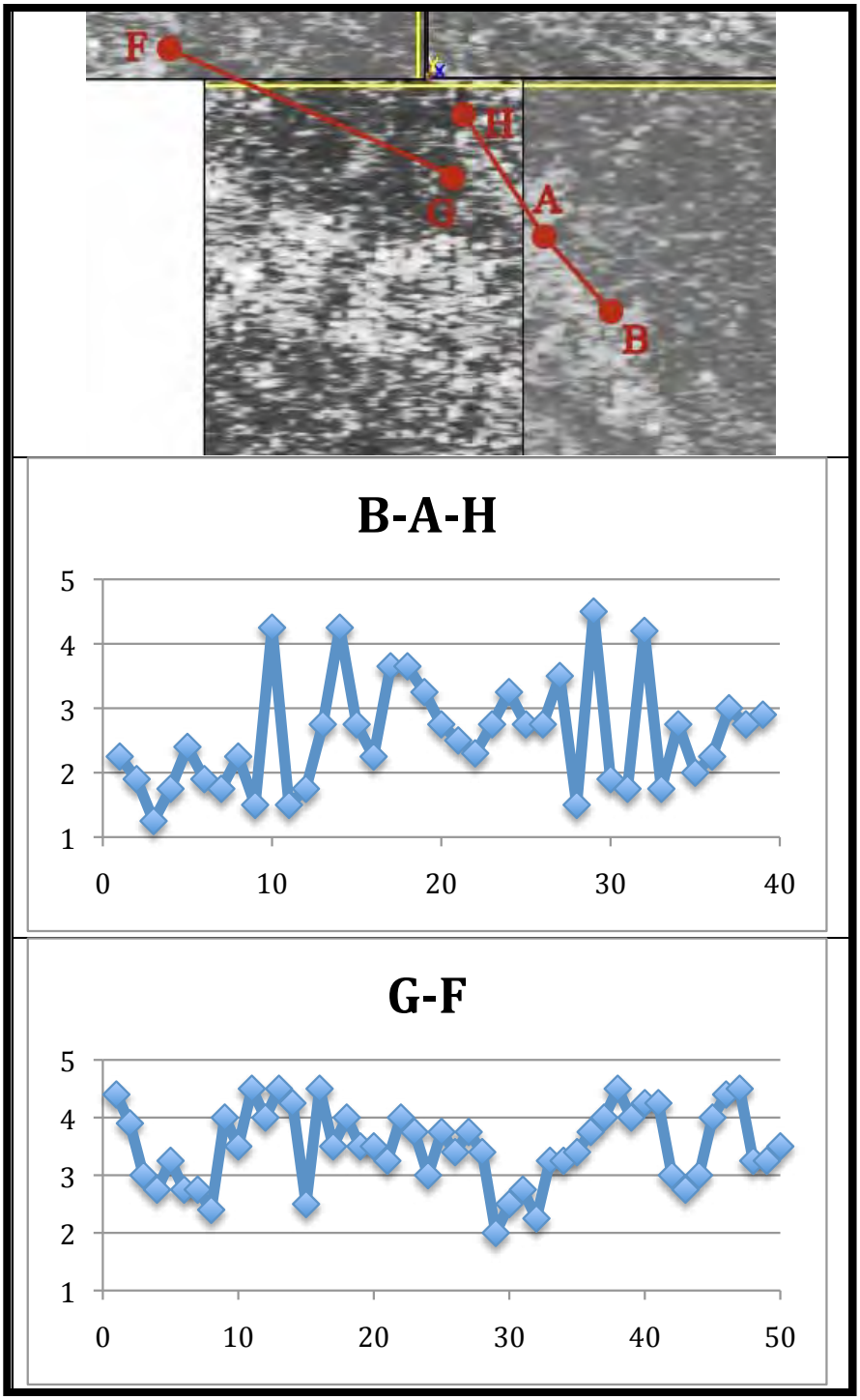
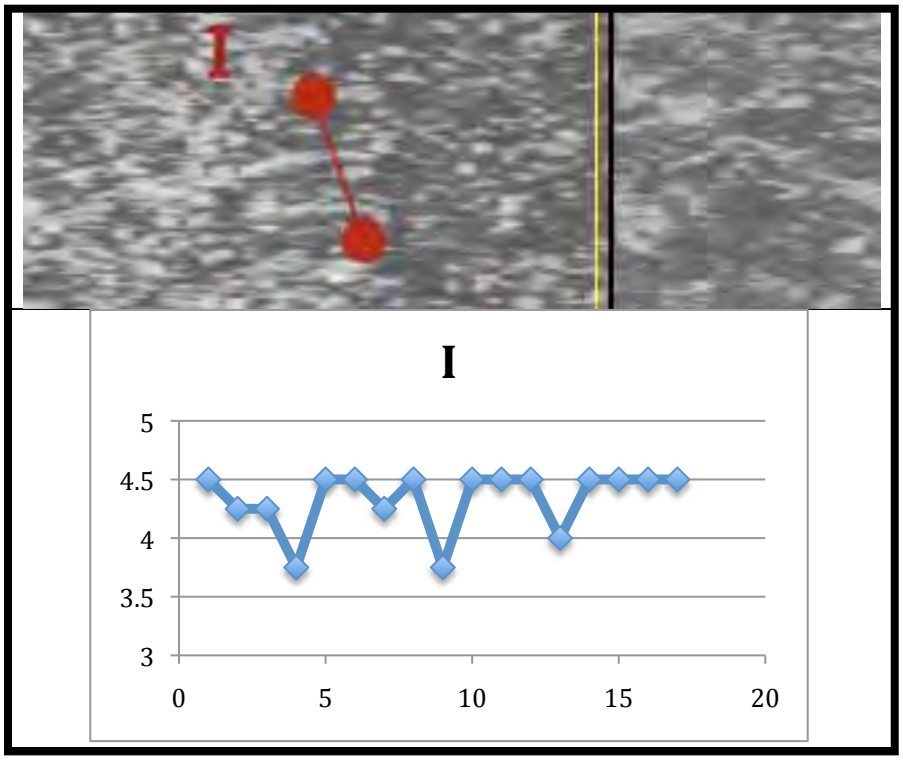


Figure 2.16. Penetrometer Graphs B-A-H and G-F. (Seramur & Associates, PC 2013, Figure 6).



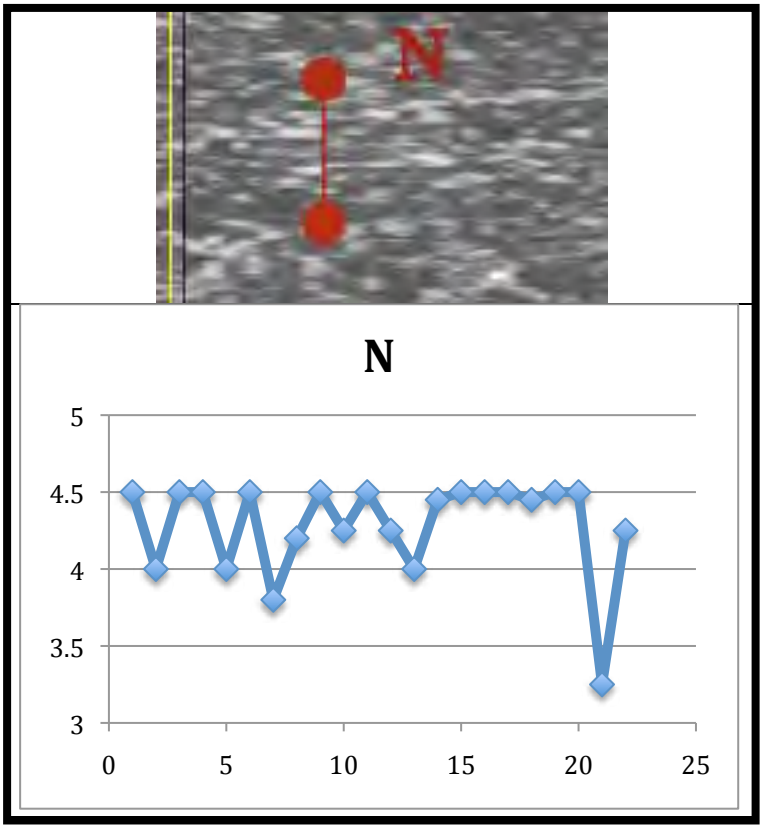
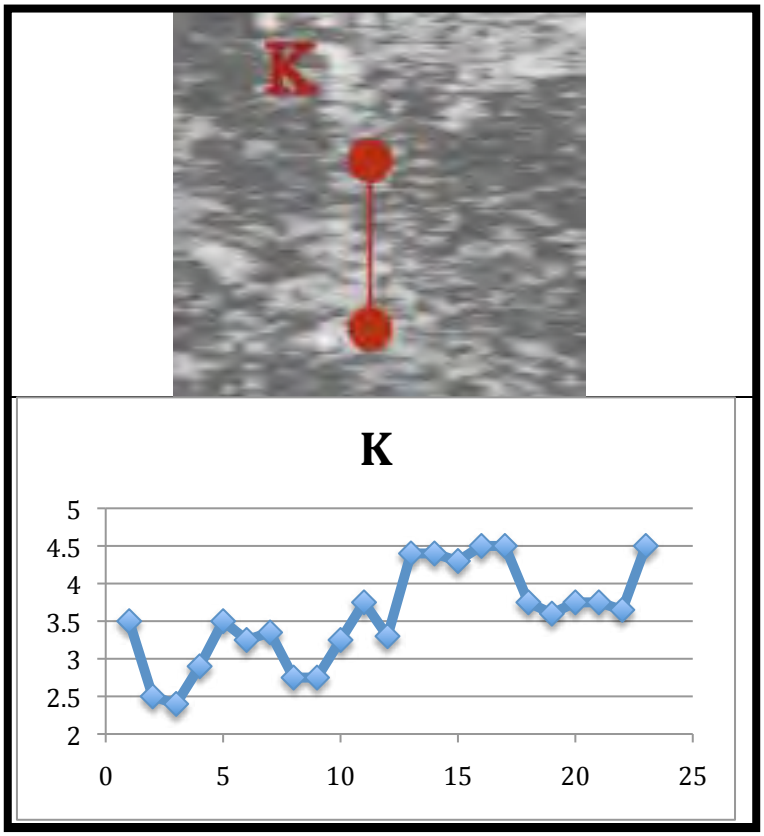


Figure 2.17. Penetrometer Graphs I and N. (Seramur & Associates, PC 2013, Figures 7 and 8).



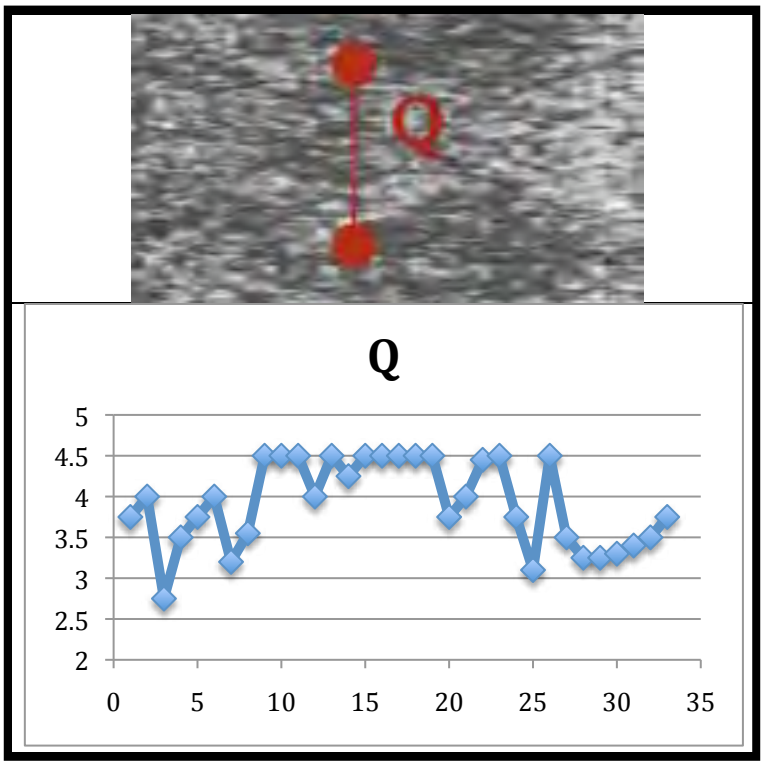


Figure 2.18. Penetrometer Graphs K and Q. (Seramur & Associates, PC 2013, Figures 9 and 10).

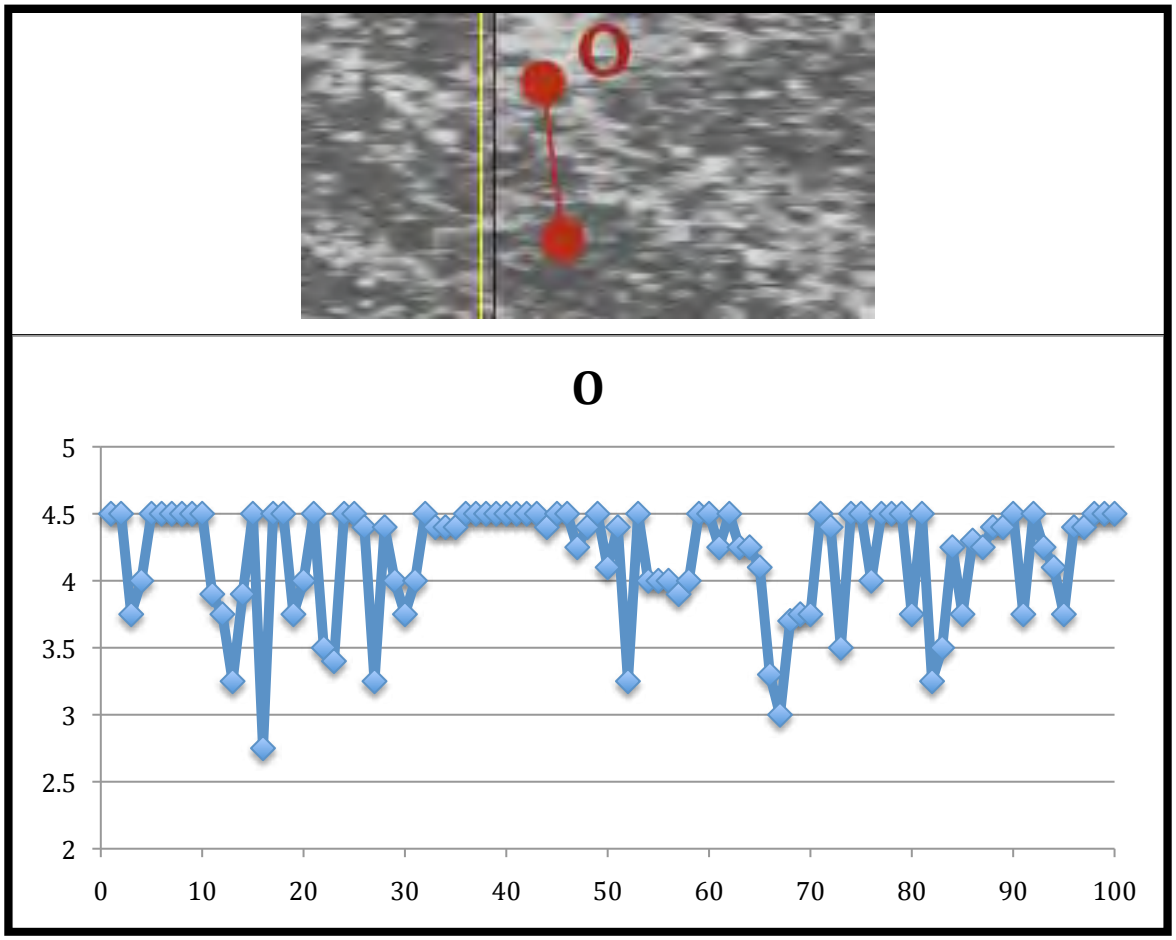
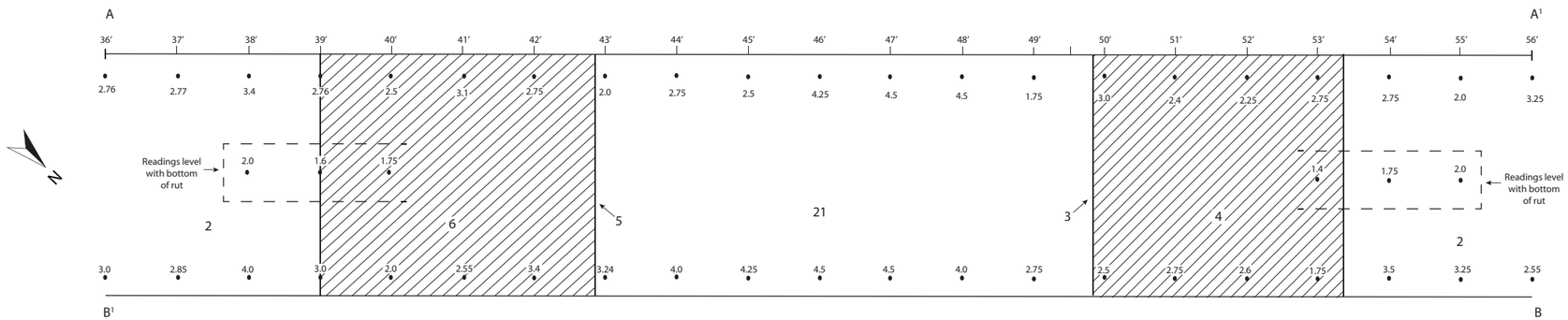


Figure 2.19. Penetrometer Graph O. (Seramur & Associates, PC 2013, Figure 10 on page 13: duplicate number).

Trench W
Plan View with Penetrometer Readings



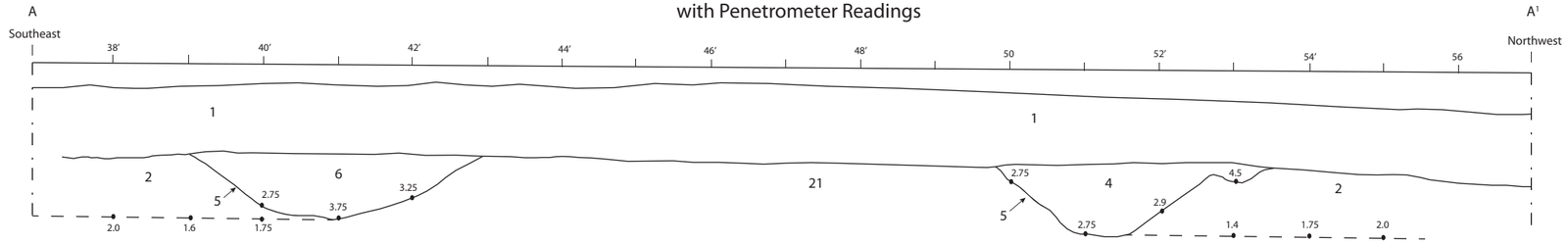
Context List

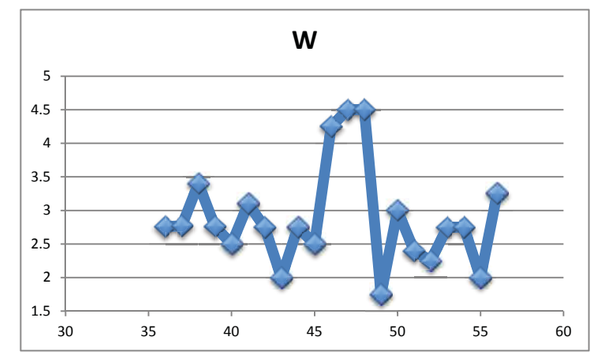
Context	Description [Interpretation]	Munsell
1	Silty loam [Ap horizon]	---
2	Silty loam [subsoil]	10 YR 5/4
3	[fill]	---
4	Silty loam [fill]	10 YR 4/4
5	[fill]	---
6	Silty loam [fill]	10 YR 4/4
21	Coarse, compact sandy loam [cart road]	10 YR 5/4

0 2
Feet

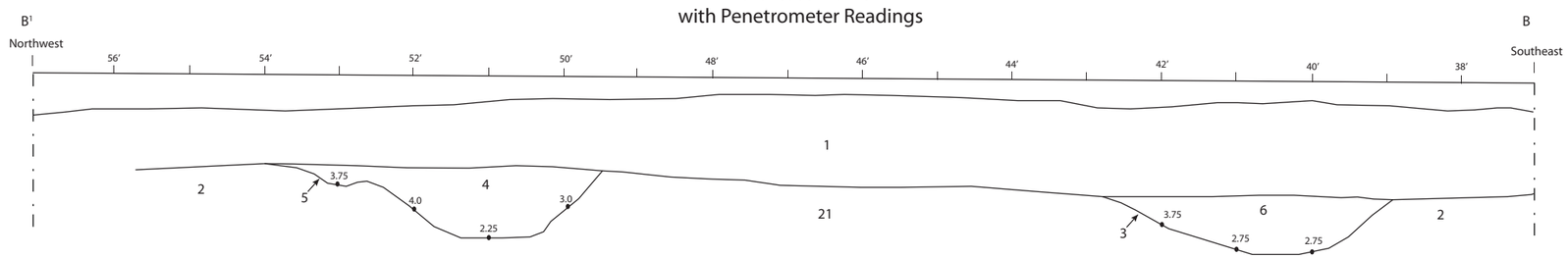
Limit of Excavation

Southwest Profile with Penetrometer Readings





Northeast Profile with Penetrometer Readings



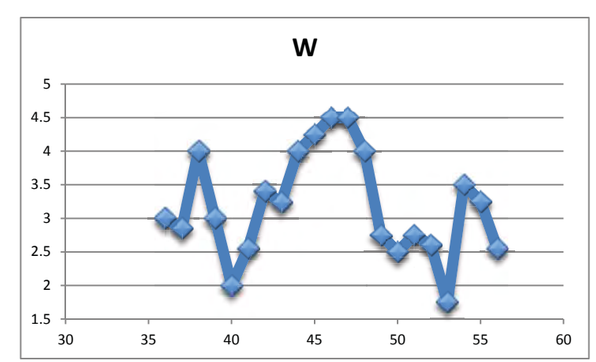


Figure 2.20. Profile and Penetrometer Graph of Trench W.

Penetrometer readings in Trench T ranged from 2.60 to 4.5+ tons/square foot (Appendix B). In this case because the trench had been excavated below the bottom of the ditches/ruts, the data did not show enough variation to produce a positive signature. Penetrometer readings in Trench U ranged from 4.5 to 4.5++ tons/square foot (Appendix B). The ground was so hard along the interior edge of the woods that readings extended beyond the instrument's scale. Readings beyond 4.5 were approximated, with one plus sign estimated to have a value of 0.5 tons/square foot. Using this approach a maximum of two plus signs could be recorded. In this case the visual identification of the ditches/ruts was more informative than the penetrometer readings, which offered little variability indicative of the cart road.

Trenches V and S were located within the agricultural field close to the wood line. It was hoped that traces might still be visible within the field where modern farm equipment would have had to turn, thus theoretically depositing soils and building up a protective layer. Stripping of the plowzone revealed some subsoil disturbances but nothing that was convincingly related to the cart road. These soils were also very compacted, with penetrometer readings in both trenches ranging from 3.75 to 4.5++ tons/square foot with almost all readings around 4.5 tons/square foot (Appendix B).

2. West Side of Spring Branch

Penetrometer readings in Trench W were taken to provide a comparison of the known data related to the path of the Cart Road to data collected from the east side of the Spring Mill Branch (Figure 2.20). Penetrometer measurements along Trench W indicated soil with the highest compaction value (4.5 tons/square foot) were located between the ditches/ruts, which had maximum values of 3.4 tons/square foot in the southern rut and 3.0 tons/square foot in the northern rut with lower values outside of the ditches/ruts (Appendix B). Readings taken from the subsoil outside of the ditches/ruts at the same depth as the bottom of the rut (2.0 tons/square foot or below) show significantly less compaction as would be expected. What was not expected was the compaction of the berm area between the ditches/ruts, which was more compact than the ditches/ruts themselves. This suggests that the weight of the draft animals (oxen, mules or horses) used to pull the heavy loads compacted the soils more than the vehicles employed to carry the cargo. This appears to confirm the suggestion that the berm area normally functioned as the cart road, while the ditches/ruts may have been used less frequently, perhaps for the placement of the runners for large sleds. This would make an excellent research and experimental topic.